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Request for grant of a patent

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1.	Your reference	ADT0172 (P7196)
2.	Patent application number *(The Patent Office will fill in this part)*	0313573.8 — 12 JUN 2003
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	QINETIQ LIMITED 85 BUCKINGHAM GATE LONDON SW1 6PD
	Patents ADP number *(if you know it)*	8183857001
	If the applicant is a corporate body, give the country/state of its incorporation	GREAT BRITAIN
4.	Title of the invention	RADIATION DETECTION APPARATUS
5.	Name of your agent *(if you have one)*	~~Barker Brettell~~
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	~~138 Hagley Road Edgbaston Birmingham B16 9PW~~ QINETIQ LTD IP FORMALITIES RM G016, A4 BLDG CODY TECHNOLOGY PARK IVELY ROAD, FARNBOROUGH HANTS, GU14 0LX
	Patents ADP number *(if you know it)*	7442494002
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country / Priority application number *(if you know it)* / Date of Filing *(day/month/year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application / Date of filing *(day/month/year)*
8.	Is a statement of inventorship and of right to grant of a patent required in support of this request *(Answer 'Yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. See note (d))*	YES

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Continuation sheets of this form	-
Description	10 + 10
Claim(s)	02 + 02
Abstract	01 + 01
Drawing(s)	03 + 03

8

10. If you are also filing any of the following, state how many against each item.

Priority documents	-
Translations of priority documents	-
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-
Request for preliminary examination *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	-
Any other documents *(please specify)*	-

11. I/We request the grant of a patent on the basis of this application.

Signature Barker Brettell

Barker Brettell

Date 11.06.2003

12. Name and daytime telephone number of person to contact in the United Kingdom

DR. ANDREW TRANTER/
DR. SEAN HARTE

Tel: 0121 456 1364

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DUPLICATE

RADIATION DETECTION APPARATUS

This invention relates to radiation detection apparatus. More particularly, but not exclusively, it relates to radiation detection apparatus for millimetre wavelength radiation, microwave radiation and/or terahertz frequency radiation.

The use of metallic wire polarising grid mirrors as focussing elements in millimetre wavelength imaging systems is known, see for example our co-pending PCT patent application number PCT/GB02/00745. Referring now to Figure 1, a millimetre wavelength imaging system 100 of the prior art comprises a curved polarising grid 102 which allows radiation 104 of a specific polarisation to pass therethrough whilst reflecting radiation of other polarisations. A small portion, typically $<10\%$, of the radiation 104a is incident upon feed horn apertures 106 of a receiver array 108. However, this small portion of the radiation is wasted as it is unfocussed and of the wrong polarisation to be received. The remainder of the radiation 104b passes through a polarisation twisting device 107, typically a quarter wave plate or Ferrite, and is reflected from an aspherical rotating mirror 110. The grid 102 reflects radiation of polarisation twisted by $90°$ 104c to a focal point, the position of the feed horn apertures 106. However such systems whilst satisfactory for long distance viewing do not provide a wide enough field of view at a short enough range to provide diffraction limited images in certain applications, for example, screening of articulated lorries for people, in a single operation.

The size of an imaging system is typically defined by the wavelength used, usually around 10mm or 3mm due to atmospheric absorption windows, the required resolution, spot size and the operating range.

Array elements are an integral and expensive part of any millimetre wavelength imaging system and increasing either the size or the number of the array elements contributes significantly to the cost of such an imaging system. The number of array elements required is proportional to the field of view of the system, and inversely proportional to the spot size.

According to a first aspect of the present invention there is provided a radiation detection apparatus comprising a radiation detector and a lens arrangement, the lens arrangement comprising a polarising element and an optical corrector, the optical corrector being located between the polarising element and the radiation detector, the optical corrector having a front surface and a non-planar rear surface, radiation impinging on the front surface being aberration corrected by the rear surface of the optical corrector towards the radiation detector, in use.

The optical corrector may be arranged to increase the diffraction limited input acceptance angle of the apparatus.

This apparatus has the advantage over the prior art that the increased acceptance angle of the apparatus results in a wider field of view at a shorter range, apparatus-subject distance due to the non-planar rear surface of the optical corrector. Use of the apparatus at short ranges, typically from 1m to about 10m, allows either a higher resolution to be achieved or smaller optics to be used, although it will be appreciated that this apparatus will have advantages at ranges in excess of 10m. This results in the ability to screen large objects, for example lorries or people, in a single pass with high resolution thereby increasing the throughput rate of the apparatus.

The non-planar rear surface of the optical corrector may be aspherical or spherical.

The optical corrector may be fabricated from a plastics material, for example polythene. The material may be a plastics foam material, typically expanded polystyrene. Preferably the optical corrector is fabricated from a material having a density of around 30 gl^{-1}. The optical corrector may be fabricated from a material having a refractive index of between 1.001 and 2.000, possibly as high as 10.0000. Preferably the material has a refractive index of about 1.0178.

The use of a plastics foam material in the formation of the optical corrector allows a lightweight optical corrector to be fabricated.

The optical corrector may be arranged to support the polarising element, typically upon the front surface thereof. The polarising element may be a wire grid, which may comprise a plurality of substantially parallel metallic wires. The polarising element may be arranged to selectively transmit radiation of a first polarisation and to selectively reflect radiation of a second polarisation. The radiation reflected by the polarising element may be focussed by the polarising element.

The support of the polarising element by the optical corrector results in a compact apparatus and maintains the polarising element in the desired optical profile to focus reflected radiation.

There may be provided a further optical corrector interposed between the optical corrector and the radiation detector. The further optical corrector may have a front surface with an elliptical or rectangular cross-section and an aspherical, plane or spherical profile. It is preferred to have an elliptical cross-section in order to minimise obscuration of the incoming

beam. The further optical corrector may have a rear surface with a different profile to the profile of the front surface.

The further optical corrector further increases the diffraction limited acceptance angle of the radiation detector.

The further optical corrector may be fabricated from a plastics material, for example polythene. The material may be a plastics foam material, typically expanded polystyrene, or a solid plastics material. Preferably the material has a density of around 30 gl^{-1}. The material may have a refractive index of between 1.001 and 2.000, in a preferred embodiment the material has a refractive index of between 1.400 and 2.000. Alternatively, the material may have a refractive index of 2.00 or more.

The radiation detector may be an imaging radiation detector and may comprise an array of detection elements. The apparatus may comprise a mirror, which may be plane, spherical or aspherical. The radiation detector may be interposed between the optical corrector and the aspherical mirror. The mirror may be arranged to rotate and may be arranged to reflect radiation that has passed through the polarising element and optical corrector. The polarising element may be arranged to focus radiation of a polarisation orthogonal to the polarisation that passed through it previously onto the detector.

The radiation detection apparatus may be arranged to detect millimetre wavelength radiation.

The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a millimetre wavelength radiation imaging apparatus of the prior art;

Figure 2 is a first embodiment of a radiation detection apparatus according to at least an aspect of the present invention;

Figure 3 is a second embodiment of a radiation detection apparatus according to at least an aspect of the present invention; and

Figures 4a to 4e are two dimensional plots of simulated point spread functions of a radiation detection apparatus, having a full field of 1920mm x 3840mm (2:1 aspect ratio) at 6.31m range and a radiation wavelength of 9mm, according to an aspect of the present invention, along with their corresponding three dimensional plots.

Referring now to Figure 2 a real time passive scanning millimetre wave imaging radiometer 200 has a scanner 202, a focussing lens arrangement 204, and an antenna feed array 206which are linked to a detector 210, typically, by waveguides.

The scanner 202 comprises a flat or slightly curved reflector plate 212, which is rotatably mounted about an axis 214, and inclined at an angle θ of approximately 3.75° to the normal to the axis 214. The focussing lens arrangement 204 comprises a focussing dish 218 and an optical corrector and support 222. The dish 218 comprises a polarisation selective reflector element 220 (e.g. a wire grid) and mounted upon a front surface 222a of the optical corrector/support 222. A quarter wave plate 216, typically a meanderline structure, lies between the focussing lens arrangement 204 and the detector 210 behind the feed array 206.

The support 222 has non-planar, aspherical front and rear surfaces 222a,b and acts as an optical corrector. The support 222 is typically made from a plastics material, for example a plastics foam material such as expanded polystyrene, which is usually transparent to radiation being detected. A high density plastic foam material with a density of about 30 gl^{-1} can be used to form the support 222. Alternatively, polyethene can be used to form the support 222. Typical refractive indices of materials used for the support 222 are in the range between 1.001 and 1.520, for example a 30gl^{-1} polystyrene foam having a refractive index of 1.0178.

The support 222 provides extra aberration correction for radiation received from a wide filed of view.

Incident radiation 225a is linearly polarised by the reflector element 220, which typically has wires inclined at 90° or 0° to the vertical so that the component of radiation with a plane of polarisation, defined by the electric vector, 0° or 90° to the vertical (90° from the line of the wires in the grid) is transmitted through the support 222.. This linearly polarised radiation, referenced 225b, encounters the meanderline plate 216. The plate 216 has the fast and slow axes of the meanderlines inclined at 45° to the direction of the wires on the reflector element 220 (and hence to the polarisation of the radiation 225b). Radiation 225c, emerging from the meanderline plate 216 is circularly polarised and is reflected from reflector plate 212 as radiation 225d, which is circularly polarised in the opposite sense to radiation 225c. When radiation 225d encounters the meanderline plate 216 it is converted back to linearly polarised radiation, radiation 225e, which has its plane of polarisation rotated by 90° in comparison with radiation 225b. When radiation 225e encounters the reflecting element 220 of the focusing dish 218 it is reflected and focused onto the feed array 206.

An inclination of the reflector plate 212 by θ causes the scanning of an angle of 4θ by the antenna.

The antenna feed array 206 typically has rows of horns, or other type of feed antenna. Each horn is connected to a detection channel, typically by a waveguide. A single detector element observes a circular scan pattern in a scene as the plate 212 rotates.

The output of each horn is fed to an amplifier, which outputs to a detector. A microprocessor receives signals from the detector 238 and processes these signals to produce an image that is displayed on a display.

This optical arrangement is a so-called conical scanning system. It is particularly compact for a specified aperture and field of view of the system.

Referring now to Figure 3, a second embodiment of a radiation detection apparatus according to the present invention is substantially similar to the first embodiment described hereinbefore with reference to Figure 2, and accordingly similar parts will be accorded similar reference numerals in the three hundred series.

A further optical corrector 350 is placed between support 322 and antenna feed array 306. The optical corrector 350 is typically 150% of the width of the feed array 306. This is due to all focussed radiation ideally passing through the further optical corrector 350. In a preferred embodiment, the further optical corrector 350 is very close to, typically < about 30mm and could even be in contact with, the detector 210 as this allows the size of the further optical corrector 350 to be minimised thereby minimising obscuration of the incoming radiation. The further optical corrector 350

has an elliptical or rectangular cross-section with an aspherically profiled front face 350a and a rear face 350b of aspherical or planar profile.

The optical corrector 350 provides still further aberration correction, and thereby allowing a further increase in the field of view over the over that for the embodiment described in relation to Figure 2.

The optical corrector 350 is typically made from a plastics material, for example a plastics foam material such as expanded polystyrene, which is usually transparent to radiation being detected. A high density plastic foam material with a density of about 30 gl^{-1} can be used to form the optical corrector 350. Alternatively, polyethene can be used to form the optical corrector 350. Typical refractive indices of materials used for the optical corrector 350 are in the range between 1.400 and 2.000, or possibly over 2.0000.

Referring now to Figures 4a to 4e, point spread functions are a measure of the response of a system to a fixed point source within the field of view of an imaging apparatus. In an ideal apparatus the point spread function is a δ-function with a normalised intensity of 1, clearly this is not possible in real apparatus as the imaging apparatus is diffraction limited and the point spread function approximately exhibits a $\text{sinc}^2\,\theta$ dependency for an apparatus with ideal feeds. However, the feeds themselves tapered response patterns and the response of the apparatus will be somewhere between the above dependency and Gaussian.

A normalised intensity the peak of a point spread function, the so-called Strehl Intensity Ratio, for an apparatus in excess of 0.8 is considered to be indicative of the imaging apparatus having good optical quality, with 1.0 being an aberration free system. Such a system is also termed "diffraction limited".

Figure 4a shows an on optical axis point spread function 402 a,b, which exhibits a normalised intensity in excess of 0.9 and narrow peak width both of which are indicative of a high quality imaging apparatus.

Figure 4b shows a point spread function 404 a,b at 481mm off optical axis, corresponding to 25% of full field of the imaging apparatus, which exhibits a normalised intensity in excess of 0.9 and narrow peak width both of which are indicative of a high quality imaging apparatus.

Figure 4c shows a point spread function 406 a,b at 961mm off optical axis, corresponding to 50% of full field of the imaging apparatus, which exhibits a normalised intensity in excess of 0.9 and narrow peak width both of which are indicative of a high quality imaging apparatus.

Figure 4d shows a point spread function 408 a,b at 1440mm off optical axis, corresponding to 75% of full field of the imaging apparatus, which exhibits a normalised intensity in excess of 0.9 and narrow peak width both of which are indicative of a high quality imaging apparatus.

Figure 4e shows a point spread function 410 a,b at 1920mm off optical axis, full field of the imaging apparatus, which exhibits a normalised intensity in excess of 0.8 and narrow peak width, both of which are indicative of a high quality imaging apparatus.

Thus, high quality images are achievable using an imaging apparatus according to the present invention at fields of view that are up to 50% larger than those achievable using current imaging apparatus, such as prior apparatus detailed in Figure 1 and especially for mm waves.

It will be appreciated that although described with reference to millimetre wave scanning imagers the present invention has wider application in the field of radiation detection apparatus and should not be limited to any particular wavelength or detection arrangement.

CLAIMS

1. A radiation detection apparatus comprising a radiation detector and a lens arrangement, the lens arrangement comprising a polarising element and an optical corrector, the optical corrector being located between the polarising element and the radiation detector, the optical corrector having a front surface and a non-planar rear surface, radiation impinging on the front surface being aberration corrected by the rear surface of the optical corrector towards the radiation detector, in use.

2. Apparatus according to Claim 1 wherein the non-planar rear surface of the optical corrector is aspherical or spherical.

3. Apparatus according to either of Claims 1 or 2 wherein optical corrector is fabricated from a material having a density of around 30 gl^{-1}.

4. Apparatus according to any preceding claim wherein the optical corrector is fabricated from a material having a refractive index of between 1.001 and 2.000.

5. Apparatus according to any preceding claim wherein there is provided a further optical corrector interposed between the optical corrector and the radiation detector.

6. Apparatus according to Claim 5 wherein the further optical corrector has a front surface with an elliptical cross-section and an aspherical, plane or spherical profile.

7. Apparatus according to either of Claims 5 or 6 wherein the further optical corrector has a rear surface with a different profile to the profile of the front surface.

8. Apparatus according to any one of Claims 5 to 7 wherein the further optical corrector is fabricated from a plastics material.

9. Apparatus according to any one of Claims 5 to 8 wherein the further optical corrector is fabricated from a plastics foam material.

10. Apparatus according to any preceding claim wherein the radiation detector is an imaging radiation detector.

11. Apparatus according to any preceding claim wherein the optical corrector is arranged to support the polarising element upon the front surface thereof

12. Apparatus according to any preceding claim wherein the polarising element is arranged to selectively transmit radiation of a first polarisation and to selectively reflect radiation of a second polarisation

13. Apparatus according to Claim 12 wherein radiation reflected by the polarising element is focussed by the polarising element

14. Apparatus according to any preceding claim wherein the radiation detection apparatus is arranged to detect millimetre wavelength radiation.

15. A radiation detection apparatus substantially as hereinbefore described with reference to Figures 2 to 4e of the accompanying drawings.

ABSTRACT

RADIATION DETECTION APPARATUS

A radiation detection apparatus (200) comprises a radiation detector (210) and a lens arrangement (218). The lens arrangement (218) comprises a polarising element (220) and an optical corrector (222). The optical corrector (222) is located between the polarising element (220) and the radiation detector (210) and has a front surface (222a) and a non-planar rear surface (222b). The optical corrector (222) is arranged to increase a diffraction limited acceptance angle of the apparatus (200).

To be accompanied, when published, by Figure 2 of the drawings.

PRIOR ART

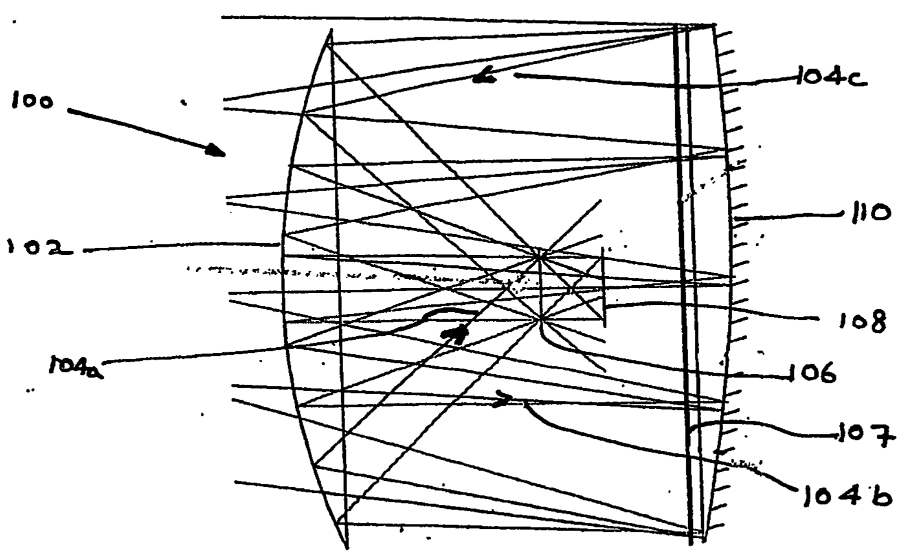

Figure 1

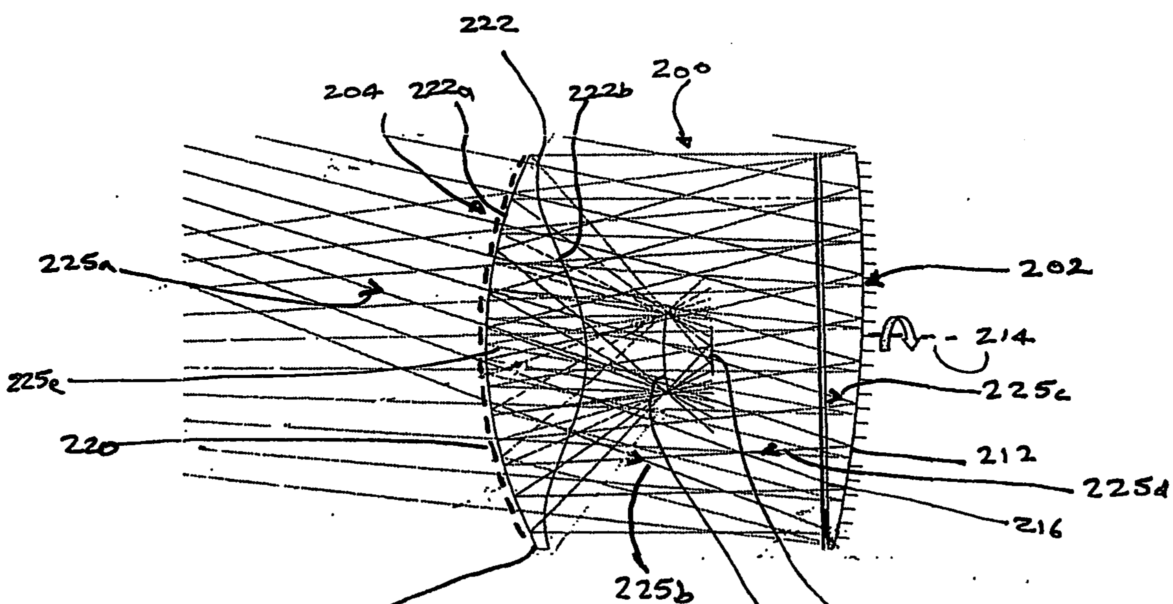

Figure 2

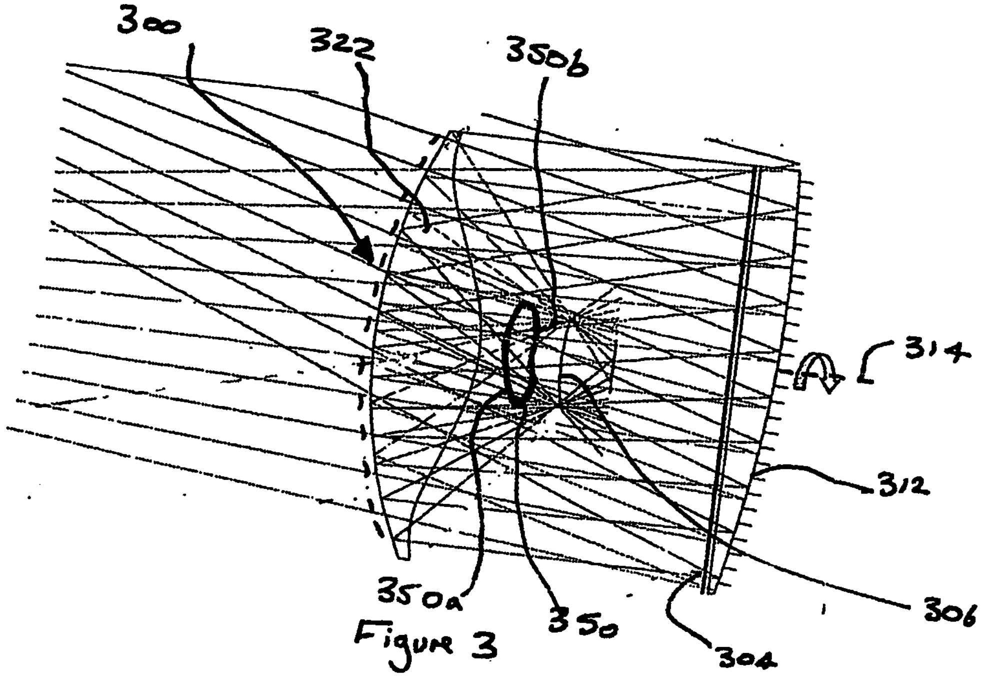

Figure 3

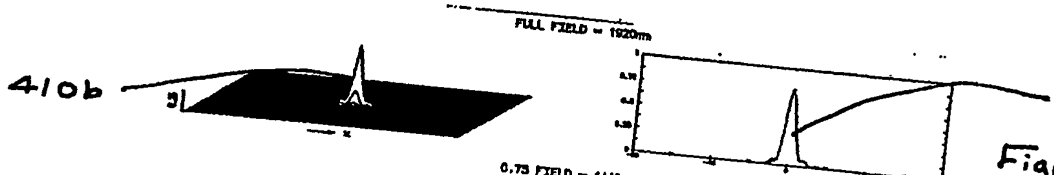

Figure 4e

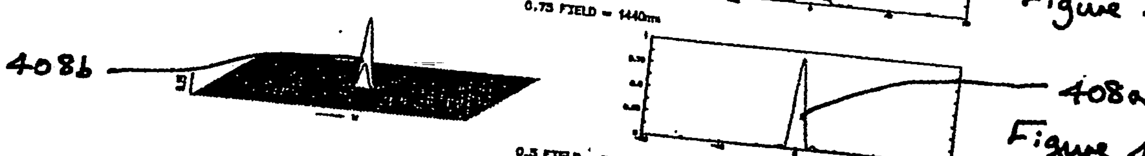

Figure 4d

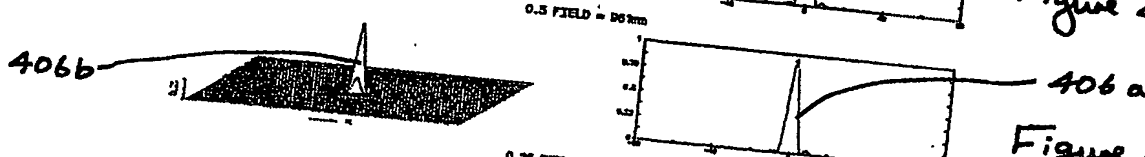

Figure 4c

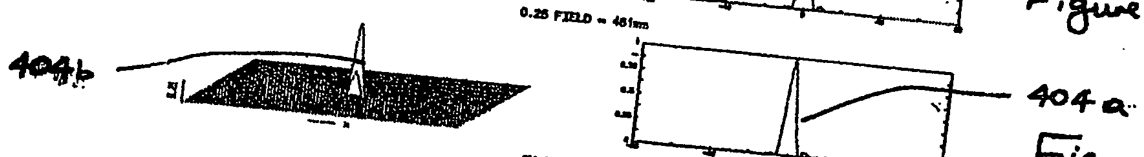

Figure 4b

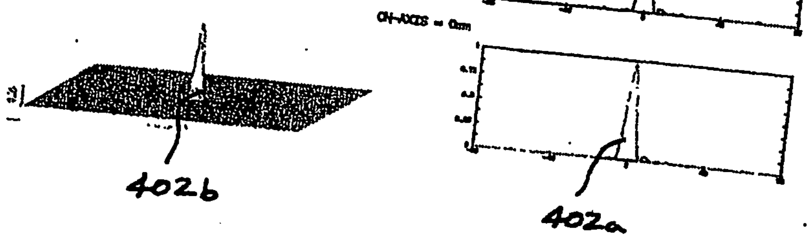

Figure 4a

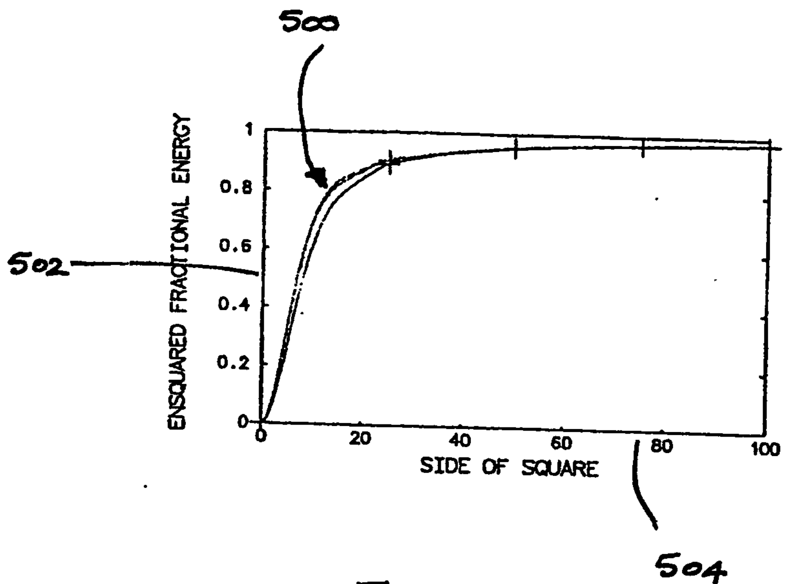

Figure 5

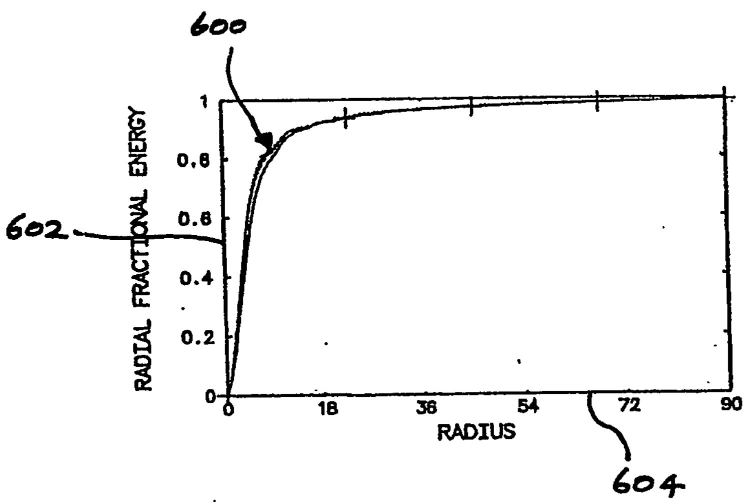

Figure 6

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